Science

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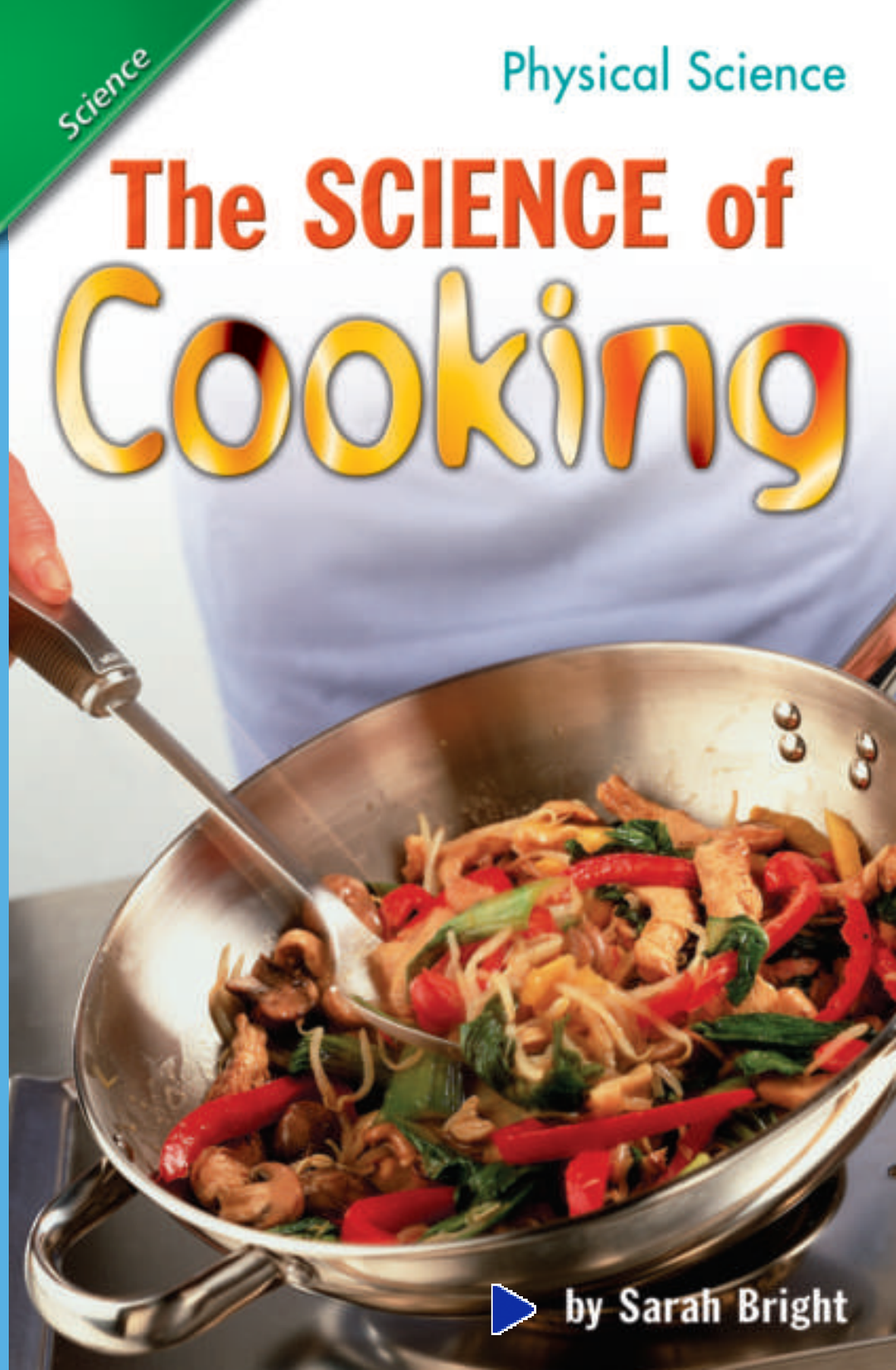
Physical Science

The SCIENCE of Cooking



by Sarah Bright

Genre	Comprehension Skill	Text Features	Science Content
Nonfiction	Compare and Contrast	• Captions • Diagram • Glossary	Light and Heat

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Vocabulary	Extended Vocabulary
conduction	braise
conductor	denaturing
convection	fluid
heat	immersed
insulator	Maillard reactions
radiation	porous
reflection	salmonella
refraction	
thermal energy	

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What You Already Know

The particles that make up matter are always in motion. They have kinetic and potential energy. The total kinetic and potential energy in a substance is called thermal energy.

Thermal energy determines how warm a substance feels. Warm liquids have more thermal energy than cool ones. The particles in warm water move more quickly, and with more kinetic energy, than those in cold water. Thermal energy can move from one substance to another. This is known as heat. Heat will always move from something that is warmer to something that is cooler. Conduction, convection, and radiation are the three ways thermal energy can be transferred. If two objects touch, the transfer of thermal energy is called conduction. Energy gets passed from particle to particle. The transfer of thermal energy by liquid or gas is called convection. This results in a stream of fluid called a convection current. If thermal energy is transferred by waves, either through matter or space, it is called radiation.

A material can be either an insulator or a conductor. An insulator does not transmit heat easily. Liquids and gases are usually good insulators because their particles are farther apart. Other materials, especially metals, are conductors. They transmit heat easily. Have you touched a cold car door on a winter day, or a metal spoon in a hot bowl of soup? You know that metal conducts heat very well.

Waves of solar radiation hit Earth every day. Some radiation is absorbed and warms Earth. Reflection occurs when radiation travels back into space.

Sound waves are compression waves; they travel through matter. Light travels as a transverse wave. It can travel through empty space, and can travel through or be absorbed by matter. Light travels slowest through solids, faster through liquids, and fastest through gases. It also changes speed when it moves from one direction to another. This is known as refraction.

Understanding the science of heat transfer helps you learn how to cook foods properly. Depending on the method we use, food can taste better, cook faster, and retain more of its nutritional value. In this book you will learn about heat sources, cooking methods, and chemical interactions that occur when preparing food.

Metal frying pans are good conductors of heat.

Heat and Cooking

Some raw foods are good for us. But much of the food we eat should be cooked. Food often tastes better and is more easily digested when it is cooked correctly. Bacteria called salmonella, which can cause infections in the digestive system, sometimes grow inside raw eggs and meat. Cooking food kills these and other harmful bacteria.

This woman is demonstrating an early cooking method using a clay oven.

Cooking involves the transfer of thermal energy. Thermal energy can be transferred by conduction, convection, and radiation. Thermal energy that moves from one substance to another is called heat. Heat can cause chemical reactions in foods.

In 1912 a French chemist named Louis Camille Maillard discovered that all foods go through a browning process at temperatures above 154°C (310°F). This process, known as the Maillard reactions, is a series of chemical reactions between sugars and proteins that produces a brown color and a taste that most people enjoy.

Sugar undergoes a chemical change when it is heated above 154°C. It breaks down and changes from a solid to a thick brown liquid you probably know as caramel.

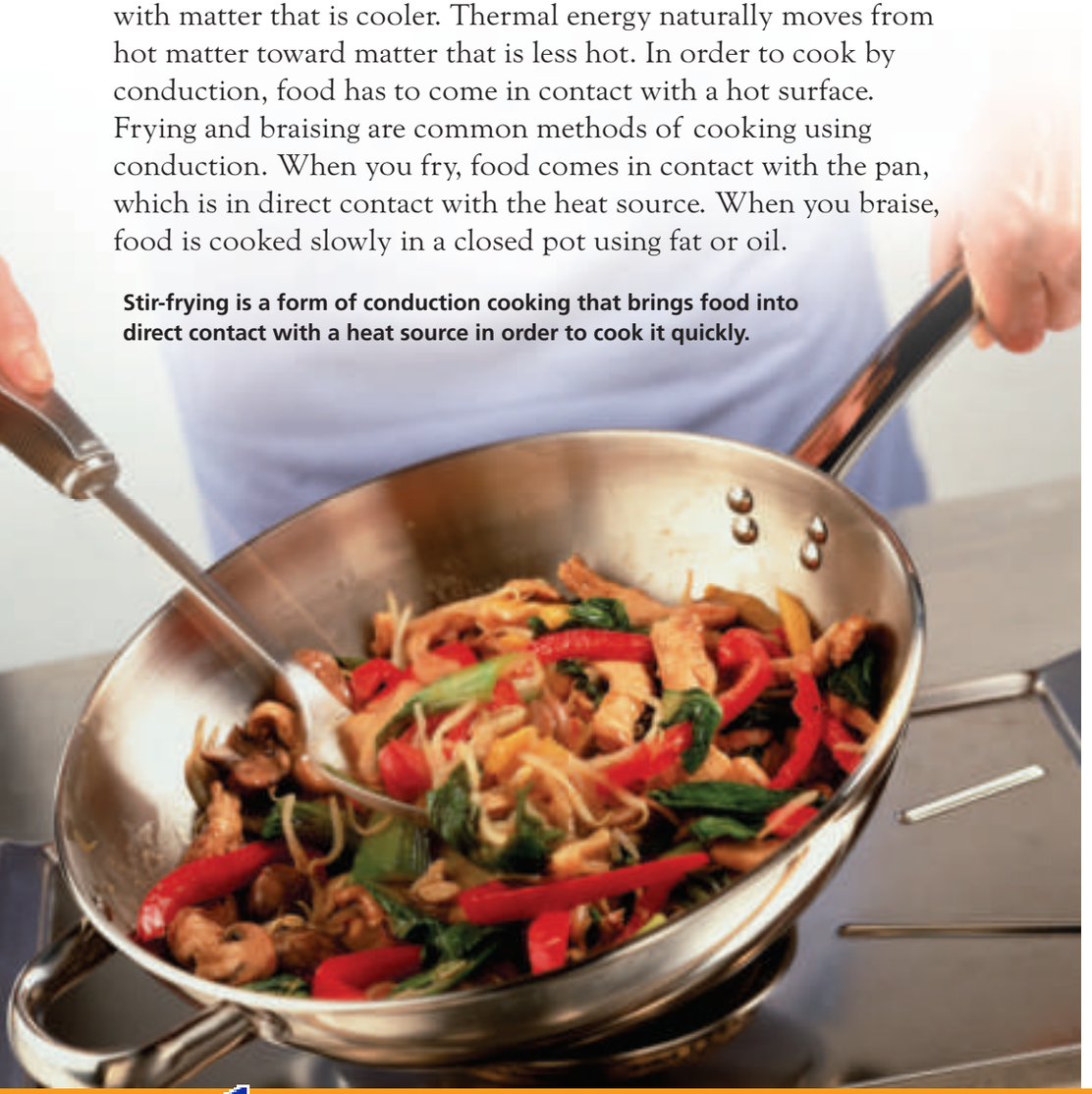
Increasing heat also makes it easier to mix things. Tea and coffee are examples of mixtures that are much easier to make with hot water than with cold water.

People have been cooking since the discovery of fire more than 500,000 years ago. Early humans cooked over an open fire; it was the only heat source available to them. Over the years people have sought to prepare safe, good-tasting food faster and more conveniently. To do this, people had to learn how to use heat. Today slow cookers, or crockpots, work for people who want food to cook over a long period of time, while microwaves cook food very quickly.

Today barbecuing is a good way to cook food. Is it really that different from how our ancestors cooked their food thousands of years ago?

Cooking With Conduction

One method of cooking is by conduction. Conduction occurs when a piece of matter that is hot comes in direct contact with matter that is cooler. Thermal energy naturally moves from hot matter toward matter that is less hot. In order to cook by conduction, food has to come in contact with a hot surface. Frying and braising are common methods of cooking using conduction. When you fry, food comes in contact with the pan, which is in direct contact with the heat source. When you braise, food is cooked slowly in a closed pot using fat or oil.



Stir-frying is a form of conduction cooking that brings food into direct contact with a heat source in order to cook it quickly.

Some materials are poor conductors of heat. Glass, wood, plastic, and water do not conduct heat well. Suppose you are stirring a pot of boiling water with a wooden spoon. Wood is a poor conductor, so the thermal energy from the water does not travel up the spoon, and your hand does not get too hot. But metals are excellent conductors. Metal pots and pans transfer heat to food easily.

Food scientists test different types of cooking utensils and cookware to see which work best in recipes. In fact, on the back of a muffin mix, you will often see different instructions for cooking times and temperatures when using different types of pans.

Since wooden skewers are poor conductors, you can use them to handle hot food without getting burned.

Which melts first?

Find a metal spoon, a plastic spoon, a wooden spoon, and a straw. Stand them in a cup. Stick a frozen pea to the end of each one with an equal amount of butter, which acts as a sort of glue. Pour warm water into the cup and see which pea falls off first. This will tell you which instrument conducted heat the fastest to melt the butter.

Convection Currents

Convection is the transfer of thermal energy by a moving fluid, such as air or water. The circular patterns created by this movement are called convection currents. When a fluid gets hot it has less density. It will rise above cooler fluids. A cooler fluid is heavier and sinks below the warmer fluid, taking its place. This means that there is a continuous, moving current of rising and falling fluids, which cook the food. To cook by convection, food needs to be immersed in fluid. Boiling is an example of convection cooking; stewing and deep-frying are other methods. Special convection ovens use fans to circulate hot air and cook food faster.

Soup is simmered rather than boiled. Simmering requires a lower temperature than boiling.

Circulation

Convection currents occur because heated oil becomes lighter and rises to the top of the bowl. As the oil cools it sinks to the bottom, creating continuous currents, or circulation. The blue food coloring in the bowl shows the circulation taking place.

When you heat a pan of water until it boils, you are causing convection currents that distribute heat throughout the pot. The boiling point of water occurs when it reaches a temperature of 100°C (212°F). Under normal pressure, the temperature of liquid water never rises above 100°C (212°F), no matter how much heat is applied. Boiling can deliver heat to food faster than any other cooking method. Deep-frying cooks food in much the same way as boiling. Hot oil surrounds a food. Water that is at the surface of the food turns to gas in the presence of the hot oil. As the water vapor leaves the food, oil from the outside gets in.

Heat Radiation

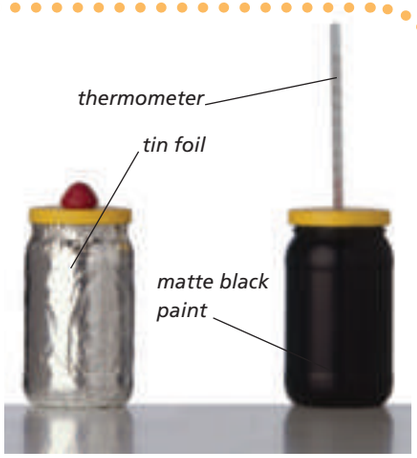
Radiation is yet another method used in cooking. Radiation is energy traveling as electromagnetic waves. When you feel sunlight on your skin, you are experiencing radiation. Your food does not have to be in contact with a hot surface or surrounded by a fluid when using radiation. A microwave oven cooks by radiation. In grilling and barbecuing, foods absorb the infrared radiation given off by the hot coals.

Microwaving cooks food faster than other cooking methods.

Unlike other methods of heating and cooking, radiation can occur in empty space. It does not rely on matter to transfer energy. This explains how the Sun's heat can reach Earth. To test this you can use radiation from the Sun to make sun tea. The energy from the Sun's rays warms the water by radiation. The tea is brewed without boiling water.

The Best Radiator

Each of the jars on the right is filled with hot water. After a few minutes, the thermometer shows that the water in the black jar cools down more quickly than the one covered with foil. Why? Because the black jar loses heat from radiation, while the foil-covered jar absorbs radiation.

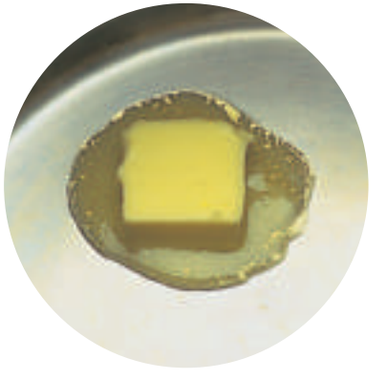


Microwave ovens are perhaps the best-known example of using radiation to cook. They are more efficient users of energy than regular or conventional ovens. Invisible waves called microwaves are produced by the oven. When they strike water molecules in food, the molecules vibrate, generating heat.

It is recommended to use only containers specially made to microwave foods. Microwave-safe containers are made of nonporous materials. Air molecules trapped in some materials, such as ceramic, can get very hot.

Barbecuing absorbs infrared radiation given off by the hot coals.

Hard or Soft?



Butter changes from hard to soft as it melts.

Many foods expand when heated and contract when cooled. Think about cookies. Bakers often shape cookies into small balls and then place them on a baking sheet. While they are in the oven, the cookies spread and become flatter as they cook. Other foods change from a soft state to a hard state. When you toast a slice of bread, it becomes hard. Bread contains carbohydrates, which are chemicals made up of carbon, hydrogen, and oxygen. When bread is toasted, the carbohydrates break down into black carbon and water. The carbon gives the bread a dark color and a crunchy texture. The water escapes into the air.

Bread changes from soft to hard as it toasts.

Eggs can be prepared using different methods of cooking. Whatever the method, cooking an egg will change the egg's form. Natural proteins in raw eggs exist in individual units. They are wound up in very tiny coils. The coils are held tightly by bonds within the molecules. When the protein is heated, some of the bonds within the individual molecules are broken. The broken bonds cause the protein to unwind, leaving the bonds exposed and sticking out. This process is called denaturing. Then the exposed bonds of the egg proteins come together, forming a solid material. This is why an egg turns solid white when it is cooked.

Hard-boiling is one way to cook an egg. Both the white and the yolk harden in the shell as they are cooked.

Temperatures

Some foods cook more quickly than others do. This can depend on the kind of liquid used for cooking. Every substance has a particular boiling point. For example, oil has a very high boiling point; it is higher than that of water. Oil is used in deep-frying, which is a very quick way to cook a potato. It takes longer to boil the potato in water. You can even deep-fry ice cream! The ice cream is covered with batter or breadcrumbs. The crust cooks so quickly that the ice cream doesn't melt.

Oil has a higher boiling point than water.

Jams and other foods with lots of sugar have high boiling points. These types of foods can be heated on a stove, but if they reach their boiling point, their chemical composition changes so much that you may end up with a gooey mess.

Water boils at 100˚C.

Cooking Science

Bread is baked in an oven using convection currents. It is one of many foods that have been cooked in much the same way for thousands of years.

There are three main ways to cook food: radiation, convection, and conduction. Often cooking uses more than one method. A pressure cooker cooks food using boiling water and hot steam. It uses conduction and convection. Steaming uses convection, while baking uses convection and sometimes conduction. Grilling uses radiation and convection, while microwaving uses radiation exclusively.

Food science helps us to discover and understand the chemical changes food goes through when it is being prepared or cooked. The more we understand the chemical processes we call cooking, the more we will benefit from the foods that sustain us.

Glossary

braise	to cook in a closed pot over low heat using fat or oil
denaturing	changing the chemical structure of a protein
fluid	a substance that lacks a definite shape such as a liquid or a gas
immersed	completely surrounded by a fluid
Maillard reactions	a series of chemical reactions through which food is browned
porous	full of small holes
salmonella	a type of bacteria that can cause infections of the digestive system

What did you learn?

1. What are the three types of heat transfer used in cooking?

2. In general, what kinds of materials are good conductors?

3. What is happening when you boil water?

4. Writing in Science Most ways of cooking use a combination of methods of heat transfer. What single way of cooking is most important in your household? What methods does it use?

5. **Compare and Contrast** Compare two different methods of cooking that use different forms of heat transfer. What are the advantages and disadvantages of each of these methods?